CERTIFICATE

This is to certify that attached English language document, identified as "Optical amplifying method, optical amplifying apparatus, and optical amplified transmission system using the apparatus", is a true and accurate translation of the original Japanese Patent Application JP 2003-034135 to the best of my knowledge and belief.

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[Title of the invention]

Optical amplifying method, optical amplifying apparatus, and optical amplified transmission system using the apparatus

[Claims]

[Claim 1] An optical amplifying method in which at least one optical amplifier is connected to an optical transmission line, an optical signal transmitted to said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, the method comprising:

detecting an optical input and output power of said optical amplifier;

obtaining a difference between gain of said optical amplifier and target gain on a basis of detected optical input and output power;

implementing a proportional calculation and an integral calculation of said difference by an automatic constant gain control device to obtain a drive current of an optical source by PI control; and

controlling gain of said optical amplifier by controlling current of said optical source based on a calculated drive current value.

[Claim 2] An optical amplifying method in which at least one optical amplifier and at least one wavelength division-multiplexing device are connected to an optical transmission line, an optical signal transmitted to said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, comprising:

at least one wavelength division-multiplexing device are connected to said optical transmission line, inputting/outputting optical signals of prescribed wavelengths to/from said optical transmission line by said optical wavelength division-multiplexing device;

detecting an optical input/output power of said optical amplifier;

obtaining a difference between gain of said optical amplifier and target gain on a basis of detected optical input/output power;

implementing a proportional calculation and an integral calculation of said difference by an automatic constant gain control device to obtain a

drive current of an optical source by PI control; and

controlling gain of said optical amplifier by controlling current of said optical source based on a calculated drive current value.

[Claim 3] The optical amplifying method as claimed in claim 1 or 2, further including detecting an optical input power to said optical amplifier, and adjusting control parameters of said automatic constant gain control device in response to a detected result, wherein a drive current of said optical source is obtained by the automatic constant gain control device with said control parameters adjusted.

[Claim 4] The optical amplifying method as claimed in claim 3, wherein in adjusting said control parameters, said optical input power from an optical device connected with said optical amplifying apparatus or said optical input power varied by add/drop function of an optical signal of wavelength division-multiplexing device in said optical device connected with said optical amplifying apparatus is detected, and the control parameters of said automatic constant gain control are adjusted in response to the detected result.

[Clam 5] The optical amplifying method as claimed in claim 3 or 4, wherein adjusting said control parameters, proportional constant of a proportional circuit in the automatic constant gain control device as said control parameters is adjusted.

[Claim 6] An optical amplifying apparatus for amplifying an optical signal on an optical transmission line, at least one optical amplifier amplifying an optical signal inputted into the optical transmission line, and an optical power detecting device for detecting an optical power of the optical signal on the optical transmission line, and an optical signal transmitted to said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, the method comprising;

a gain detecting device to detect gain of said optical amplifier;

a difference obtaining device to obtain difference between a detected gain and a target gain; and

an automatic constant gain control device for implementing a proportional calculation and an integral calculation of said difference to calculate a drive current of an optical source and controlling gain of said

optical amplifier to be constant by controlling current of said optical source based on a calculated drive current value.

[Claim 7] An optical amplifying apparatus for amplifying an optical signal on an optical transmission line, at least one optical amplifier amplifying an optical signal inputted into the optical transmission line, and an optical power detecting device for detecting an optical power of the optical signal on the optical transmission line, and an optical signal transmitted to said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, comprising;

a wavelength division-multiplexing device for add/drop function of an optical signal of a prescribed wavelength to/from said optical transmission line;

a gain detecting device to detect gain of said optical amplifier;

a difference obtaining device to obtain difference between a detected gain and a target gain; and

an automatic constant gain control device for implementing a proportional calculation and an integral calculation of said difference to calculate a drive current of an optical source and controlling gain of said optical amplifier to be constant by controlling current of optical source based on a calculated drive current value.

[Claim 8] The optical amplifying apparatus as claimed in claim 6 or 7, further comprises an adjusting device for adjusting control parameters of said automatic constant gain control device in response to a detected result of an optical input power to said optical amplifier which is detected by the optical power detecting device, the automatic constant gain control device with said control parameters adjusted controlling gain of the optical amplifier in response to optical input/output power detected by the optical power detecting device.

[Claim 9] The optical amplifying apparatus as claimed in claim 8, wherein said adjusting device adjusts control parameters of said automatic constant gain control device in response to a detected result of said optical input power from an optical device connected with said optical amplifying apparatus detected by said optical power detecting device or said optical input power varied by add/drop function of an optical signal of wavelength

division-multiplexing device in said optical device connected with said optical amplifying apparatus.

[Claim 10] The optical amplifying apparatus as claimed in claim 8 or 9, wherein said automatic constant gain control device includes a differential circuit for subtracting gain of the optical amplifier from a target gain, that yields a difference between gain of the optical amplifier and a target gain, and a proportional circuit for multiplying proportional constant of the proportional circuit and said difference, and said adjusting device adjusts proportional constant of the proportional circuit as the control parameters.

[Claim 11] An optical amplified transmission system for amplifying an optical signal transmitted to the optical transmission line by a plurality of optical amplifying apparatuses connected in series including at least one optical amplifying apparatus as claimed in any one of claims 6-10.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[FIELD OF THE INVENTION]

The present invention relates to an optical amplifying method for adjusting control parameters in an automatic constant gain control circuit to control gain of an optical amplifier, an optical amplifying apparatus and an optical amplified transmission system using the apparatus.

[0002]

[PRIOR ART]

A conventional optical amplifying apparatus 10, for example as shown in Fig. 17, includes an optical amplifier 11 connected to an optical transmission line 1. An optical signal inputted into the optical amplifier 11 and an optical signal outputted from the optical amplifier 11 and passed through an erbium-doped fiber (EDF) 12 are divided by optical couplers 13, 14 respectively, and then optical input power and optical output power thereof are detected by photo diodes (PD) 15, 16 respectively in the optical amplifying apparatus 10. The optical input power and the optical output power are converted to voltages corresponding to the optical powers in monitor circuits 17, 18, and the voltages are outputted to a control circuit 19, respectively. The control circuit 19 controls a pump laser diode 20 based on the voltages to implement an automatic constant gain control (AGC) in the optical amplifier 11, thus controlling the gain of the optical amplifier to be a prescribed value.

[0003]

As one of the optical transmission system, there is a wavelength division multiplexing (WDM) system in which a plurality of optical signals of different wavelengths are division-multiplexed and simultaneously transmitted on a single fiber-optical transmission line. The optical signals are optically amplified through a plurality of optical amplifying apparatuses placed in the optical transmission line, and then transmitted to an optical transmission line of a single-mode fiber (SMF) or a dispersion-shifted fiber (DSF) in the WDM system.

[0004]

There is a case where the optical amplifying apparatuses are applied in an optical transmission line in multistage connection and an optical

amplified transmission system is established. In the optical amplified transmission system, caused by an increase of transmission distance and transmission capacity, data traffic increases rapidly. And the increase of data traffic incurs a decrease of transmission performance. Consequently, a wavelength division multiplexing (WDM) system is being diffused to prevent the decrease of transmission performance.

[0005]

In the optical amplifying apparatus implementing the AGC, the optical output power is controlled so as to maintain the gain to be constant, when the number of wavelengths in the WDM optical signal varies and the optical input power to the optical amplifier varies accordingly. However, when a transient characteristics of power control of the optical amplifier is not appropriate in the transitional period when the optical input power abruptly varies, the control of the optical output power corresponding to a variation of the optical input power of the optical amplifier is delayed. Fig. 18(a) shows the variation of the optical input power of the optical amplifier. Fig. 18(b) shows the result (i.e., delay). In this case, the optical output power per one wavelength channel largely varies (refer to Fig. 18(c)), thus deteriorating the transmission quality of the optical signal in the transitional period when the optical input power abruptly varies.

[0006]

In conventional optical amplifying apparatus, which for example Patent Literature 1 shows, the apparatus provides a delay portion on the optical transmission line in which the variation of the number of the wavelengths is detected by the AGC circuit, and a transmission of the optical signal is delayed such that time required for controlling the gain of the optical amplifier equals to time required for inputting the optical signal to the optical amplifier, thus prevents a variation of the optical output power of the optical amplifier. More specifically, as shown in Fig. 19, an optical amplifying apparatus includes a delay portion 21 to delay the transmission of the optical signal on the optical transmission line between the optical coupler 13 at the input side of the optical amplifier 11 and the optical amplifier 12. In the optical amplifying apparatus, the time required for controlling the gain by the AGC circuit 19 is set to be the time required for the transmission of the optical signal, thus avoiding the variation of the optical output power as shown in Fig. 18(b).

[0007]

[PATENT LITERATURE 1]

Japanese Patent Publication No. 2001-053682 (Page 3-5, Fig. 1)

[0008]

[PROBLEM TO BE SOLVED]

However, the above mentioned conventional optical amplifying apparatus causes a problem in which an additional space for locating an optical fiber in the delay portion is required, since the delay portion utilizes the optical fiber in order to delay optical signal on the transmission line, thus disturbing a realization of a down sizing of the apparatus.

[0009]

An object of the invention is to provide an optical amplifying method, an optical amplifying apparatus and an optical amplified transmission system, in which the space occupied by the optical fiber may be reduced to realize the downsizing of the apparatus, and the control constant of the AGC circuit is adjusted to be an appropriate value even when the optical input power to the optical amplifier abruptly varies under operation, thus enabling high speed optical signal transmission and stable optical amplifier control.

[0010]

[MEANS TO SOLVE THE PROBLEM]

To achieve the above mentioned purposes, an optical amplifying method in Claim 1 in which at least one optical amplifier is connected to an optical transmission line, an optical signal transmitted to said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, the method comprising: detecting an optical input and output power of said optical amplifier; calculating a difference between gain of said optical amplifier and target gain on a basis of detected optical input and output power; implementing a proportional calculation and an integral calculation of said difference by an automatic constant gain control device to calculate a drive current of an optical source by PI control; and controlling gain of said optical amplifier by controlling current of said optical source based on a calculated drive current value is applied in the invention.

[0011]

In this embodiment, the difference between the gain obtained from the optical input/output power and the target gain is calculated, the proportional integral control is implemented based on the difference to calculate the current of the optical source LD (LD current), and the gain of the optical amplifier is controlled in correspondence to the calculated LD current, thus, the variation of the optical output power per wavelength channel is maintained small so as to suppress the affection to the transmission quality, in addition, the space occupied by the optical fiber is reduced so as to realize a downsizing of the apparatus.

[0012]

An optical amplifying method in Claim 2, in which at least one optical amplifier and at least one wavelength division-multiplexing device are connected to an optical transmission line, an optical signal transmitted through said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to the optical power of thus detected, the method comprising: at least one wavelength division-multiplexing device are connected to said optical transmission line, inputting/outputting optical signals of prescribed wavelengths to/from said optical transmission line by said optical wavelength division-multiplexing device; detecting an optical input/output power of said optical amplifier; obtaining a difference between gain of said optical amplifier and target gain on a basis of detected optical input and output power; implementing a proportional calculation and an integral calculation of said difference by an automatic constant gain control device to calculate a drive current of an optical source by PI control; and controlling gain of said optical amplifier by controlling current of said optical source based on a calculated drive current value is applied in the invention.

[0013]

In this embodiment, the optical input/output power varied according to the add/drop function of the optical signal wavelength number by the wavelength division-multiplexing device such as the OADM (Optical Add-Drop Multiplexer), is monitored, the difference between the gain thus obtained and the target gain is calculated, the proportional integral control

is implemented based on the difference to calculate the current of the optical source (LD current), and the gain of the optical amplifier is controlled in correspondence to the calculated LD current, thus, the variation of the optical output power per one wavelength channel is maintained small so as to suppress the affection to the transmission quality, in addition, the space occupied by the optical fiber is reduced so as to realize the downsizing of the apparatus.

[0014]

The optical amplifying method in Claim 3, further including detecting an optical input power to said optical amplifier, and adjusting control parameters of said automatic constant gain control device in response to a detected result, wherein a drive current of said optical source is calculated by the automatic constant gain control device with said control parameters adjusted.

[0015]

In this embodiment, since the optical input/output power of the optical amplifier is monitored, and since the control parameters in the AGC circuit is adjusted in correspondence to the monitored optical input power, the invention enables the optical amplifying apparatus to control transient gain appropriately even when the optical input power to the optical amplifier abruptly varies under operation. Thus, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0016]

The optical amplifying method in claim 4, wherein in adjusting said control parameters, said optical input power from an optical device connected with said optical amplifying apparatus or said optical input power varied by add/drop function of an optical signal of wavelength division-multiplexing device in said optical device connected with said optical amplifying apparatus is detected, and the control parameters of said automatic constant gain control is adjusted in response to the detected result is applied in the invention.

[0017]

In this embodiment, since the optical input power from the optical device connected with said optical amplifying apparatus or the optical input power

varied by the add/drop function of the optical signal wavelength number by the wavelength division-multiplexing device such as the OADM on the upstream, is monitored to adjust the control parameters of the automatic constant gain control circuit, the invention enables the optical amplifying apparatus to control transient gain appropriately even when the optical input power to the optical amplifier abruptly varies under operation. Thus, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0018]

The optical amplifying method in claim 5, wherein adjusting said control parameters, proportional constant of a proportional circuit in the automatic constant gain control device as said control parameters is adjusted is applied in the invention.

[0019]

In this embodiment, since the control parameters comprises the proportional constant of the proportional circuit, and the proportional constant of the proportional circuit is adjusted, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0020]

An optical amplifying apparatus in Claim 6, for amplifying an optical signal on an optical transmission line, at least one optical amplifier amplifying an optical signal inputted into the optical transmission line, and an optical power detecting device for detecting an optical power of the optical signal on the optical transmission line, and an optical signal transmitted through said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, comprising; a gain detecting device to detect gain of said optical amplifier; a difference calculating device to obtain difference between a detected gain and a target gain; and an automatic constant gain control device for implementing a proportional calculation and an integral calculation of said difference to calculate a drive current of an optical source and controlling gain of said

optical amplifier to be constant by controlling current of said optical source based on a calculated drive current value is applied in the invention.

[0021]

In this embodiment, the optical input/output power is monitored by the optical power detecting device to detect the gain, the difference between the detected gain and the target gain, and the said difference is calculated, the proportional integral control is implemented based on the difference to calculate the current of the optical source (LD current), and the gain of the optical amplifier is controlled in correspondence to the calculated LD current, thus, the space occupied by the optical fiber is reduced so as to realize the downsizing of the apparatus, and the variation of the optical output power per one wavelength channel is maintained small so as to suppress the affection to the transmission quality.

[0022]

An optical amplifying apparatus in Claim 7, for amplifying an optical signal on an optical transmission line, at least one optical amplifier amplifying an optical signal inputted into the optical transmission line, and an optical power detecting device for detecting an optical power of the optical signal on the optical transmission line, and an optical signal transmitted through said optical transmission line is amplified by said optical amplifier while an optical power of the optical signal on the optical transmission line is detected, and gain of the optical amplifier is controlled in response to an optical power of thus detected, comprising; a wavelength division-multiplexing device for add/drop function of an optical signal of a prescribed wavelength to/from said optical transmission line; a gain detecting device to detect gain of said optical amplifier; a difference calculating device to obtain difference between a detected gain and a target gain; and an automatic constant gain control device for implementing a proportional calculation and an integral calculation of said difference to calculate a drive current of an optical source and controlling gain of said optical amplifier to be constant by controlling current of optical source based on a calculated drive current value is applied in the invention.

[0023]

In this embodiment, the apparatus includes the wavelength division-multiplexing device such as the OADM. Since the optical input/output power varied according to the add/drop function of the optical

signal wavelength number by the wavelength division-multiplexing device, is monitored to calculate the gain, the difference between the calculated gain and the target gain, and since the said difference is calculated, and the proportional integral control is implemented based on the difference to calculate the current of the optical source (LD current), and the gain of the optical amplifier is controlled in correspondence to the calculated LD current, thus, the variation of the optical output power per one wavelength channel is maintained small so as to suppress the affection to the transmission quality, in addition, the space occupied by the optical fiber is reduced so as to realize the downsizing of the apparatus is applied in the invention.

[0024]

The optical amplifying apparatus in claim 8, further comprises an adjusting device for adjusting control parameters of said automatic constant gain control device in response to a detected result of an optical input power to said optical amplifier which is detected by the optical power detecting device, the automatic constant gain control device with said control parameters adjusted controlling gain of the optical amplifier in response to optical input/output power detected by the optical power detecting device is applied in the invention.

[0025]

In this embodiment, since the optical input/output power of the optical amplifier is monitored, and the control parameters is adjusted in correspondence to the monitored optical input power, the invention enables the optical amplifying apparatus to control transient gain appropriately even when the optical input power to the optical amplifier abruptly varies under operation. Thus, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0026]

The optical amplifying apparatus in claim 9, wherein said adjusting device adjusts control parameters of said automatic constant gain control device in response to a detected result of said optical input power from an optical device connected with said optical amplifying apparatus detected by said optical power detecting device or said optical input power varied by

add/drop function of an optical signal of wavelength division-multiplexing device in said optical device connected with said optical amplifying apparatus is applied in the invention.

[0027]

In this embodiment, since the optical input power from the optical device connected with said optical amplifying apparatus or the optical input power varied by the input signal of a prescribed wavelength by the wavelength division-multiplexing device arranged in the said optical device connected with said optical amplifying apparatus is monitored by means of said detecting device, the invention enables the optical amplifying apparatus to control transient gain appropriately even when the optical input power to the optical amplifier abruptly varies under operation. Thus, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0028]

The optical amplifying apparatus in claim 10, wherein said automatic constant gain control device includes a differential circuit for subtracting gain of the optical amplifier from a target gain, that yields a difference between gain of the optical amplifier and a target gain, and a proportional circuit for multiplying proportional constant of the proportional circuit and said difference, and said adjusting device adjusts proportional constant of the proportional circuit as the control parameters is applied in the invention.

[0029]

In this embodiment, since the control parameters to be adjusted comprises the proportional constant of the proportional circuit in the automatic constant gain control device, and since the proportional constant of the proportional circuit is adjusted by the adjusting device, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0030]

An optical amplified transmission system in Claim 11, for amplifying an optical signal transmitted to the optical transmission line by a plurality of optical amplifying apparatuses connected in series including at least one

optical amplifying apparatus is applied in the invention.

[0031]

In this embodiment, since a plurality of the optical amplifying apparatuses in the above embodiment are connected in series on the optical transmission line, the transient characteristics of the gain control of the optical amplifier in the overall optical amplified transmission system is improved to enable to realize a stable transmission of the optical signal.

[0032]

[EMBODIMENTS OF THE INVENTION]

Referring now to the drawings Fig. 1-16, the embodiments of the optical amplifying method, the optical amplifying apparatus, and the optical amplified transmission system using the apparatus of the present invention will be explained in detail. For convenience of explanation, the same numeral numbers are used in the following drawing as the elements in Fig. 17.

[0033]

(First embodiment)

Fig. 1 is a diagram showing the first embodiment of the optical amplifying apparatus of the present invention. The automatic constant gain control (AGC) in the optical amplifying apparatus is implemented by a proportional integral control (hereinafter referred to as "PI control"), for example. A control circuit 19 implementing the AGC comprises a differential circuit 19a to which the voltages from logarithmic transformation circuits 17, 18 are inputted, a proportional circuit 19b and an integral circuit 19c to both of which a difference ΔG from the differential circuit 19a is inputted, an adder circuit 19d to which the output values from the proportional circuit 19b and the integral circuit 19c are inputted, and a laser diode current control circuit 19e to which a calculated value from the adder circuit 19d is inputted.

[0034]

More specifically, the input/output power of an optical amplifier 11 are converted by a photo diode (PD) 15, 16 and a logarithmic transformation circuit 17, 18 to voltages Vin, Vout corresponding to the respective optical powers, and inputted to the differential circuit 19a. In addition to the voltages Vin and Vout, a voltage G0 corresponding to the target gain set from outside is inputted. The differential circuit 19a calculates the

difference ΔG between the present gain (Vout-Vin) of the optical amplifier 11 and the target gain G0, and outputs the difference ΔG to the proportional circuit 19b and the integral circuit 19c.

$$\Delta G = G0\text{-}(Vout\text{-}Vin)$$

[0035]

The proportional circuit 19b outputs a value ($k \cdot \Delta G$) obtained by multiplying the inputted deference ΔG by the proportional constant k which is pre-set as a fixed value. The integral circuit 19c outputs an integral value $[(1/\tau) \cdot \int \Delta G\, dt]$ of ΔG. Where, $\tau = RC$, R and C are a resistance of the resistor and a capacitance of the capacitor respectively in the integral circuit 19c.

[0036]

Those output values ($k \cdot \Delta G$) and $[(1/\tau) \cdot \int \Delta G\, dt]$ are inputted to the adder circuit 19d. The adder circuit 19d adds those values to calculate a laser diode current value I0.

$$I0 = k \cdot \Delta G + (1/\tau) \cdot \int \Delta G\, dt$$

[0037]

The adder circuit 19d outputs the calculated value I0 to the LD current control circuit 19e. The LD current control circuit 19e controls a current of an pump LD 20 based on the value I0.

[0038]

As described above, in the above embodiment of the optical amplifying apparatus, the input/output power of the optical amplifier 11 which is logarithmic-transformed by the PD 15, 16 and the logarithmic transformation circuit 17, 18, and the target gain are inputted to the differential circuit 19a to calculate the difference between the present gain of the optical amplifier and the target gain, and the PI control is implemented such that the difference equals to zero, according to the target gain of the optical amplifier. As a result, it is not necessary to arrange a large space occupied by the optical fiber as in the conventional optical amplifying apparatus, thus realizing the down sizing of the apparatus.

[0039]

Furthermore, in the above embodiment of the optical amplifying apparatus, as shown in Fig. 18, in order to suppress the variation of the optical output power per one wavelength channel to be small so as to reduce affection to the transmission quality, the proportional constant k of the proportional

circuit in the control circuit is set to be somewhat large to adjust the response time of the control circuit, thus improving the transient characteristics of the gain control in the optical amplifier. However, if the proportional constant k is enlarged too much, the optical output from the optical amplifier becomes unstable.

[0040]

Fig. 2 is a diagram showing a relation between a proportional constant of the proportional circuit and the optical input power. As illustrated in the drawing, the proportional constant required to obtain the transient characteristics not affecting the transmission quality and the threshold for the proportional constant causing the optical output to be unstable, depends on the optical input power to the optical amplifier. More specifically, when the optical input power is small, the even small proportional constant can provide appropriate transient characteristics, and the threshold for oscillation becomes small in the case that the input power abruptly varies. Contrary to the above, when the optical input power becomes large, even though a margin to prevent an unstable operation becomes large, the large proportional constant is required to obtain appropriate transient characteristics.

[0041]

In such case, as shown in Fig. 3, when the dynamic range is relatively narrow, for example, even when the proportional constant k of the proportional circuit is set to be constant, i.e., k=k0, the optical output from the optical amplifier 11 is stable at either upper limit or lower limit of the dynamic range, thus not affecting transient characteristics.

[0042]

However, when the number of channel wavelength increases in the WDM transmission system, the optical input/output dynamic range is extended wide, as illustrated in Fig. 4. Accordingly, when the proportional constant of the proportional circuit is maintained constant, the response speed of the control circuit is slow at the vicinity of the upper limit of the dynamic range (i.e., in case that the optical input power is large), thus the device may not realize appropriate transient gain control characteristics. Furthermore, the proportional constant of the proportional circuit exceeds the threshold for oscillation at the vicinity of the lower limit of the dynamic range, thus the device may cause an unstable output power and gain

control.

[0043]

(Second embodiment)

In the second embodiment of the optical amplifying apparatus of the invention, the apparatus includes a function to adjust the proportional constant of the proportional circuit in the control circuit, thus enabling to adjust the proportional constant of the proportional circuit in correspondence to the optical input power of the optical amplifier. More specifically, according to the second embodiment of the optical amplifying apparatus, the proportional constant of the proportional circuit is adjusted to be large when the optical input power is large, and the proportional constant of the proportional circuit is adjusted to be small when the optical input power is small.

[0044]

Fig. 5 is a diagram describing the second embodiment of the optical amplifying apparatus of the present invention. The same numeral numbers are used in the following drawing as the elements in Fig. 1.

[0045]

As shown in Fig. 5, the optical amplifying apparatus of this embodiment comprises the first stage optical amplifying apparatus and the second stage optical amplifying apparatus 10, 10, which are the same composition, connected to the optical transmission line 1, and the Optical Add/Drop Multiplexer (OADM) 31 connected between two optical amplifying apparatuses 10 and 10 as a wavelength division-multiplexing device. The above mentioned two stages optical amplifying apparatus may be used in the repeater terminal of the WDM transmission system for example.

The OADM 31 drops an optical signal of a specific wavelength from the optical signals transmitted from the first stage optical amplifying apparatus 10, or add an optical signal of a specific wavelength to the optical signals transmitted from the first stage optical amplifying apparatus 10. Then OADM 31 outputs the multiplexed optical signals to the second stage optical amplifying apparatus 10.

Although the detailed explanation is omitted, since each of the optical amplifying apparatus 10, 10 is the same composition as the optical amplifying apparatus as shown in Fig. 1, the first stage optical amplifying apparatus 10 monitors the optical input power of the signal transmitted

from the upstream repeater terminal to implement the AGC, while the second stage optical amplifying apparatus 10 monitors the optical input power of the signal transmitted from the local OADM 31 to implement the AGC.

[0046]

The AGC circuit 19 of the optical amplifying apparatus 10 as shown in Fig. 5 is different from the AGC circuit as shown in Fig. 1 in that there is provided a proportional constant adjusting circuit 19f in which the proportional constant of the proportional circuit 19b is adjusted in correspondence to the voltage Vin of the optical input power from the logarithmic transformation circuit 17, for example as shown in Fig. 6.

[0047]

Furthermore, since the AGC circuit 19 is arranged as described above, the proportional circuit 19b comprises a comparator 19b1, a fixed resistor 19b2 and a variable resistor 19b3 as shown in Fig. 7. As the variable resistor 19b3, a Digitally Controlled Potentiometer (hereinafter referred to as "DCP") is applied, which enables to digitally adjust the proportional constant by a CPU, for example. As a result, the resistance of the variable resistor can be changed by means of the adjusting function of the proportional constant adjusting circuit 19f, even if the apparatus is under the operation.

[0048]

The proportional constant of the proportional circuit 19b is determined by a ratio of the resistance R1 of the fixed resistor 19b2 to the resistance R2 of the variable resistor 19b3, as follows:

$$k = R2/R1 \qquad (1)$$

[0049]

The proportional constant adjusting circuit 19f monitors the optical input power through the logarithmic transformation circuit 17 from the PD 15, and adjusts the proportional constant of the proportional circuit 19b corresponding to the optical input power Pin. More specifically, the proportional constant adjusting circuit 19f controls the resistance R2 of the variable resistor 19b3 in the proportional circuit 19b so as to be large when the optical input power Pin is large, thus adjusting the proportional constant k to be large. Contrary to the above, the proportional constant adjusting circuit 19f controls the resistance R2 of the variable resistor 19b3 in the

proportional circuit 19b so as to be small when the optical input power Pin is small, thus adjusting the proportional constant k to be small.

[0050]

For example, the proportional constant adjusting circuit 19f, as shown in Fig. 8, adjusts the proportional constant k of the proportional circuit 19b to be as follows:

$$K = A \cdot Pin + B \qquad (2)$$

Where, Pin is the optical input power, and the voltage Vin in correspondence to the optical input power Pin is provided for the proportional constant adjusting circuit 19f by way of the logarithmic transformation circuit 17. And A and B are constant, and are uniquely determined by a desirable proportional constant value k of the proportional circuit and two optical input power values at least.

[0051]

An adjusting operation of the proportional constant of the proportional circuit in the optical amplifying apparatus 10 is explained with reference to the flow chart as shown in Fig. 9. Where, the proportional constant of the proportional circuit 19b is to be controlled to a target value $\pm\delta$ (δ is an arbitrary number). As shown in the figure, the optical input power Pin is inputted from the PD 15 through the logarithmic transformation circuit 17 to the AGC circuit 19 (Step 101).

[0052]

The gain adjusting circuit 19f calculates the target proportional constant k0 based on the inputted optical input power Pin in the AGC circuit 19 (Step 102). The above mentioned calculation is executed by substituting the value of the optical input power Pin for the above equation (2). Then, the resistance R2 of the DCP (i.e., the resistance of the variable resistor 19b3 as shown in Fig. 7) is inputted from the proportional circuit 19b to the gain adjusting circuit 19f (Step 103), and the present proportional constant k is calculated by applying the above equation (1) (Step 104).

[0053]

The proportional constant adjusting circuit 19f obtains the difference Δk by the calculated target proportional constant k0 in the Steps 102 and 104 and the present proportional constant k, applying the following: $\Delta k = k - k0$ (Step 105), and then determines whether Δk is larger than $-\delta$ or not (Step 106).

[0054]

When $-\delta \geqq \Delta k$, it is determined that the proportional constant is out of the range of the target value$\pm\delta$, and the resistance R2 of the DCP is controlled to increase one step (Step 107). When$-\delta < \Delta k$, it is to be determined whether Δk is smaller than $+\delta$ (Step 108).

[0055]

Here, the proportional constant adjusting circuit 19f determines that the proportional constant is out of the range of the target value$\pm\delta$, when $\Delta k \geqq +\delta$, and controls the resistance R2 of the DCP so as to reduce one step (Step 109). The proportional constant adjusting circuit 19f determines that the gain is within the range of the target value$\pm\delta$, when $\Delta k<\delta$, and returns to the Step 101 without controlling the DCP to execute an adjusting operation of the proportional constant in relation to the next monitored optical input power Pin.

[0056]

As described above, in this embodiment of the apparatus, since the proportional constant adjusting circuit to adjust the proportional constant of the proportional circuit is provided in the AGC circuit to continuously adjust the proportional constant in correspondence to the optical input power. Thus the proportional constant of the proportional circuit is changed to be the small value in the vicinity of the lower limit of the dynamic range, therefore preventing the optical amplifier from unstable output power operation.

Furthermore, the proportional constant of the proportional circuit is changed to be the large value in the vicinity of the upper limit of the dynamic range where the margin for the oscillation of the control circuit is large, thus enabling the response speed of the control circuit to be fast so that the transient characteristics of the gain control of the optical amplifier is improved to reduce the deterioration of the transmission characteristics of the optical signal when the optical power abruptly varies.

[0057]

(Third embodiment)

It is proposed in the second embodiment of the apparatus that the gain is continuously adjusted by applying DCP. However, the present invention is not limited thereto, and the invention can adjust the gain of the proportional circuit by applying analog switches.

Fig. 10 is a circuit diagram showing a second example of the

proportional circuit as shown in Fig. 6. As shown in Fig. 10, in the proportional circuit 19b, a plurality of resistors R1 to Rn (n is an arbitrary integer number) having different resistances in place of the DCP are connected in parallel, and each of the analog switches S1 to Sn is connected in series to the respective corresponding resistors R1 to Rn.

[0058]

The gain adjusting circuit 19f controls to switch the analog switches S1 to Sn in response to the monitored optical input power so that the resistances of the resistors R21 to R2n (n is an arbitrary integer number) connected to the comparator 19b1 are changed, thus enabling to adjust the proportional constant of the proportional circuit.

[0059]

For example, as shown in Fig. 11, the proportional constant is set to select one of three stages k1, k2, k3 in the proportional constant adjusting circuit 19f where it satisfies k1<k2<k3. The proportional constant adjusting circuit 19f controls to switch to a resistor having a small resistance within the resistors R1 to Rn in the proportional circuit 19b when the monitored optical input power Pin is smaller than P1, thus adjusting the proportional constant to be small proportional constant k1.

The proportional constant adjusting circuit 19f controls to switch to a resistor having a medium resistance within the resistors R1 to Rn in the proportional circuit 19b when the monitored optical input power Pin is within the range from P1 to P2, thus adjusting the proportional constant to be medium proportional constant k2. The proportional constant adjusting circuit 19f controls to switch to a resistor producing a larger resistance within the resistors R1 to Rn in the proportional circuit 19b when the monitored optical input power Pin is larger than P2, thus adjusting the proportional constant to be large proportional constant k3.

[0060]

An adjusting operation of the proportional constant of the proportional circuit in the optical amplifying apparatus 10 including the proportional constant adjusting circuit 19f is explained with reference to the flow chart as shown in Fig. 12. As shown in Fig. 12, the AGC circuit 19 reads in the optical input power Pin from the PD 15 through the logarithmic transformation circuit 17 (Step 201). The proportional constant adjusting circuit 19f in the AGC circuit 19 determines whether the read optical input

power Pin is smaller than P1 (i.e., Pin<P1) or not (Step 202).

[0061]

Here, the proportional constant adjusting circuit 19f controls to switch to a resistor producing a small resistance within the resistors R1 to Rn in the proportional circuit 19b when Pin < P1, thus adjusting the proportional constant k to be proportional constant k1 (Step 203). When Pin≧P1, the proportional constant k is maintained to be the present state (Step 204), and then, the gain adjusting circuit 19f determines whether being Pin<P2 or not (Step 205).

[0062]

The proportional constant adjusting circuit 19f controls to switch to a resistor producing a medium resistance within the resistors R1 to Rn in the proportional circuit 19b when Pin < P2, thus adjusting the proportional constant k to be proportional constant k2 (Step 206).

Furthermore, the proportional constant adjusting circuit 19f controls to switch to a resistor producing a large resistance within the resistors R1 to Rn in the proportional circuit 19b when Pin≧P2, thus adjusting the proportional constant k to be large proportional constant k3 (Step 207).

[0063]

As described above, in this embodiment of the apparatus, since the proportional constant adjusting circuit to adjust the proportional constant of the proportional circuit is provided in the AGC circuit to intermittently adjust the proportional constant in response to the optical input power, the proportional constant of the proportional circuit is changed to be the small value in the vicinity of the lower limit of the dynamic range, thus preventing the optical amplifier from unstable output power operation, as same as in the second embodiment.

Furthermore, the proportional constant of the proportional circuit is changed to be the large value in the vicinity of the upper limit of the dynamic range where the margin for the oscillation of the control circuit is large, thus enabling the response time of the control circuit to be fast so that the transient characteristics of the gain control of the optical amplifier is improved to reduce the deterioration of the transmission characteristics of the optical signal when the optical power abruptly varies.

[0064]

The effect of the present invention is verified according to the measured

comparative results of the third embodiment of the apparatus and the apparatus in which the proportional constant of the proportional circuit is fixed. The optical amplifying apparatus comprising the first stage optical amplifying apparatus and the second stage optical amplifying apparatus as shown in Fig. 5 is used for measuring the effect, in which the first stage optical amplifying apparatus and the second stage optical amplifying apparatus implement the independent AGC, respectively.

[0065]

The first stage optical amplifying apparatus is connected to the second optical amplifying apparatus by an attenuator in place of the OADM. As the optical signal, four wavelength channels of the surviving signal and twelve wavelength channels of the excursion signal within the wavelength band from 1530.33[nm] to 1561.42[nm] are used, and the optical input to the first stage optical amplifying apparatus is increased from four wavelength to sixteen wavelength by means of switching on/off the excursion signal, thus changing the total optical input power to four times (i.e., 6[dB] increases).

[0066]

Furthermore, the optical power per one wavelength channels is set to be –12[dBm/ch] and –24[dBm/ch], and the total optical input power is measured in two cases (i.e., one case in which the optical input power is varied in the vicinity of the upper limit of the dynamic range (i.e., changed from –6[dBm] to 0[dBm]), and the other case in which the optical input power is varied in the vicinity of the lower limit of the dynamic range (i.e., changed from –18[dBm] to -12[dBm])). The transient response of the optical output power per one wavelength channels in the 1530.33[nm] is measured in the optical output from the second stage optical amplifying apparatus when the optical input power varies.

[0067]

The relation between the proportional constant of the proportional circuit and the optical input power in the two stage-optical amplifying apparatus is as shown in Figs. 13. Fig. 13(a) shows the relation between the proportional constant and the optical input power in the first stage optical amplifying apparatus. Fig. 13(b) shows the relation between the proportional constant and the optical input power in the second stage optical amplifying apparatus.

[0068]
For comparison, the optical power is measured in the conventional apparatus with the proportional constant fixed in which the proportional constant k of the first stage optical amplifying apparatus is fixed to be 3.0, and the proportional constant k of the second stage optical amplifying apparatus is fixed to be 3.2 in either cases when the optical input power is high (refer to Fig. 14(a)), or when the optical input power is low (refer to Fig. 14(b)).
[0069]
The optical power is measured in the apparatus of the third embodiment of the invention with the proportional constant adjusted in which the proportional constant k of the first stage optical amplifying apparatus is set to be 3.1 and the proportional constant k of the second stage optical amplifying apparatus is set to be 4.3 when the optical input power is high (refer to Fig. 15(a)), while the proportional constant k of the first stage optical amplifying apparatus is set to be 1.7 and the proportional constant k of the second stage optical amplifying apparatus is set to be 1.2 when the optical input power is low (refer to Fig. 15(b)).
[0070]
The result shows that when the proportional constant is fixed as in the conventional apparatus, the optical output power per one wavelength channel largely varies to the corresponding variation of the optical input power shown in the case that the optical input power is large in Fig. 14(a), thus deteriorating the transmission quality of the optical signal when the optical input power varies. Furthermore, the optical output power per one wavelength channel becomes unstable to the corresponding variation of the optical input power shown in the case that the optical input power is small in Fig. 14(b).
[0071]
Contrary to the above, when the proportional constant is adjusted as in the apparatus of the third embodiment of the invention, the optical output power per one wavelength channel varies small to the corresponding variation of the optical input power shown in the case that the optical input power is large in Fig. 15(a), since the proportional constant is set to be large, thus the transient output power characteristics becomes superior so as to improve the transmission quality of the optical signal when the optical

input power varies.

Furthermore, the optical output power per one wavelength channel becomes stable to the corresponding variation of the optical input power shown in the case that the optical input power is small in Fig. 14(b), since the proportional constant is set to be small.

[0072]

As is clear from the measured results, when the corresponding proportional constant is set and adjusted in response to the variation of the optical input power to the optical amplifier even under operation, the response time of the control circuit is adjusted to improve the transient characteristics of the gain control of the optical amplifier, thus enabling to realize a stable optical transmission.

[0073]

(Fourth embodiment)

Fig. 16 is a partial system diagram of the optical amplified transmission system comprising a multiple stages (connected in series) of the optical amplifying apparatuses of the first embodiment as shown in Fig. 5. The optical amplifying apparatus 30 functions as a repeater terminal. In the repeater terminal 30, OADM 31 adds a part of the optical signal transmitted from the upstream terminal (forward repeater terminal), or drops new wavelength channels to optical signal transmitted from the upstream terminal.

In case that the number of the wavelengths of the optical signal multiplexed by the OADM 31, are twice increased, the optical power in the second stage optical amplifying apparatus 10 is increased to two times of the original optical input power. For example, the optical input power corresponding to six wavelength channels are increased to the optical input power corresponding to twelve wavelength channels.

[0074]

However the automatic constant gain control can maintain the optical power per one wavelength channel to be constant in the repeater terminal of this embodiment, since the proportional constant of the proportional circuit in the AGC circuit 19 is adjusted in response to the optical input power of the optical amplifier.

So that the response of the optical amplifier in this embodiment remains the same in spite of various optical input power to the amplifier. Thus the gain

of the optical amplifier 11 is controlled independently of the number of the input wavelength channels.

[0075]

Furthermore, in this embodiment of the repeater terminal, since the proportional constant of the proportional circuit is adjusted independently in each repeater terminal, the proportional constant of the proportional circuit is changed to be the small value in the vicinity of the lower limit of the dynamic range, thus preventing the optical amplifier from unstable output power operation.

Furthermore, the proportional constant of the proportional circuit is changed to be the large value in the vicinity of the upper limit of the dynamic range where the margin for the oscillation of the control circuit is large, thus enabling the response speed of the control circuit to be fast so that the transient characteristics of the gain control of the optical amplifier is improved to reduce the deterioration of the transmission characteristics of the optical signal when the optical power abruptly varies. As a result, accumulated optical power variation of the optical signal in multiple repeater terminals in series can be effectively suppressed, thus enabling to realize a stable transmission of the optical signal.

[0076]

The invention is not limited to the embodiments described above. Various modification of the embodiments of the invention may be made without departing from the spirit and scope thereof. For example, although the analog control of the AGC circuit is explained in the embodiment, the digital control of the AGC circuit applying a processing unit is also included in the present invention.

[0077]

[Effect of the Invention]

As described above, since the optical amplifying method and optical amplifying apparatus of the invention monitors the input/output power of the optical amplifier is monitored by means of the PD or logarithmic circuit to detect the gain, the difference between the detected gain and the target gain , and since the said difference is calculated by the AGC circuit, and since proportional integral control is implemented based on the difference to control the gain of the optical amplifier, the variation of the optical output power per one wavelength channel may be maintained small so as to

suppress the affection to the transmission quality, in addition, the space occupied by the optical fiber may be reduced so as to realize the downsizing of the apparatus.

[0078]

Since the optical amplifying method and optical amplifying apparatus of the invention monitors input/output power of the optical amplifier which is varied by add/drop function of the optical signal of a prescribed wavelength produced by the wavelength division-multiplexing device, by means of the PD or logarithmic circuit to detect the gain, the difference between the detected gain and the target gain, and since the said difference is calculated by the AGC circuit, and since the proportional integral control is implemented based on the difference to control the gain of the optical amplifier, the variation of the optical output power per one wavelength channel may be maintained small so as to suppress the affection to the transmission quality, in addition, the space occupied by the optical fiber may be reduced so as to realize the downsizing of the apparatus.

[0079]

The optical amplifying method and optical amplifying apparatus of the invention enables the optical amplifying apparatus to control transient gain appropriately even if the optical input power to the optical amplifier abruptly varies under operation, since the optical input power of the optical amplifier is monitored by means of the PD or logarithmic circuit, and the control parameters in the AGC circuit in correspondence to the monitored optical input power. Thus, the response time of the control circuit is optimized so as to improve the transient characteristics of the gain control of the optical amplifier and to enable to realize a stable optical transmission.

[0080]

Since the optical amplifying method and optical amplifying apparatus of the invention monitors input/output power of the optical amplifier which is varied by add/drop function of the optical signal of a prescribed wavelength produced by the wavelength division-multiplexing device, by means of the PD or logarithmic circuit to detect the gain, the difference between the detected gain and the target gain, and since the said difference is calculated by the AGC circuit, and since the proportional integral control is implemented based on the difference to control the gain of the optical

amplifier, the variation of the optical output power per one wavelength channel may be maintained small so as to suppress the affection to the transmission quality, in addition, the space occupied by the optical fiber may be reduced so as to realize the downsizing of the apparatus.

[0081]

The optical amplifying method and optical amplifying apparatus of the invention enables the optical amplifying apparatus to control transient gain appropriately even if the optical input power to the optical amplifier abruptly varies under operation, since the optical input power of the optical amplifier is monitored, and since the optical input power from the upstream optical amplifier which is connected to the said amplifier is monitored, and since optical input power transmitted from the wavelength division-multiplex device which is connected to the said amplifier is monitored, and since the control parameters in the AGC circuit in correspondence to the monitored optical input power.

[0082]

The optical amplifying method and optical amplifying apparatus of the invention enables the optical amplifying apparatus to suppress the variation of output power per one wavelength channel when the optical input power to the optical amplifier abruptly varies under operation,

since the proportional constant of the proportional circuit in the automatic constant gain control circuit is adjusted in correspondence to the optical input power, in order to optimize the control parameters against operational condition of the said optical amplifier.

[0083]

Since the optical amplified transmission system of the invention comprises a multiple stages of the above mentioned optical amplifier in claims 6-10 which are connected in series on the optical transmission line, the transient characteristics of the gain control of the optical amplifier in the overall optical amplified transmission system is improved. Thus, the deterioration of the transmission characteristics of the optical signal is suppressed when the optical power varies and the optical power variation of the optical signal in multiple repeater terminals in series can be effectively reduced, thus enabling to realize a stable transmission of the optical signal.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a diagram showing the first embodiment of the optical amplifying apparatus of the present invention:

Fig. 2 is a diagram showing a relation between proportional constant in the automatic constant gain control and the optical input power:

Fig. 3 is a diagram showing a relation between the optical input power and proportional constant in the automatic constant gain control when the optical input dynamic range is narrow:

Fig. 4 is a diagram showing a relation between the optical input power and proportional constant in the automatic constant gain control when the optical input dynamic range is wide:

Fig. 5 is a diagram showing the second embodiment of the optical amplifying apparatus of the present invention:

Fig. 6 is a diagram showing an example of the AGC circuit of the two stages-optical amplifying apparatus as shown in Fig. 5:

Fig. 7 is a circuit diagram showing a first example of the proportional circuit as shown in Fig. 6:

Fig. 8 is a diagram showing a relation between an optical power and the proportional constant adjusted by the proportional constant adjusting circuit as shown in Fig. 7:

Fig. 9 is a flow chart explaining an adjusting operation of the proportional constant of the optical amplifying apparatus of the present invention:

Fig. 10 is a circuit diagram showing a second example of the proportional circuit as shown in Fig. 6:

Fig. 11 is a diagram showing a relation between an optical power and the proportional constant adjusted by the proportional constant adjusting circuit as shown in Fig. 10:

Fig. 12 is a flow chart explaining an adjusting operation of the proportional constant of the optical amplifying apparatus of the present invention including a proportional constant adjusting circuit as shown in Fig. 11:

Fig. 13 is a diagram showing a relation between an optical input power and the proportional constant in the first stage AGC circuit as shown in Fig. 5:

Fig. 14 is a waveform diagram showing a measuring result of a transient characteristics of the optical power in case that the optical input

power varies when the proportional constant is fixed in the automatic constant gain control:

Fig. 15 is a waveform diagram showing a measuring result of transient characteristics of the optical power in case that the optical input power varies when the third embodiment is applied:

Fig. 16 is a partial system diagram of the optical amplified transmission system using the optical amplifying apparatus as shown in Fig. 5:

Fig. 17 is a diagram showing an example of the conventional optical amplifying apparatus:

Fig. 18 is a schematic graph showing transient characteristics of the optical power in case that the optical input power varies:

Fig. 19 is a diagram showing other example of the conventional optical amplifying apparatus:

[DESCRIPTION OF REFERENCE NUMERAL]

1 optical transmission line

10 optical amplifying apparatus

11, 12 optical amplifiers

13, 14 optical couplers

17, 18 logarithmic transformation circuits (monitor circuits)

19 AGC circuit

19a differential circuit

19b proportional circuit

19b1 comparator

19b2 fixed resistor

19b3 variable resistor

19c integral circuit

19d adder circuit

19e LD current control circuit

19f proportional constant adjusting circuit

20 pump LD

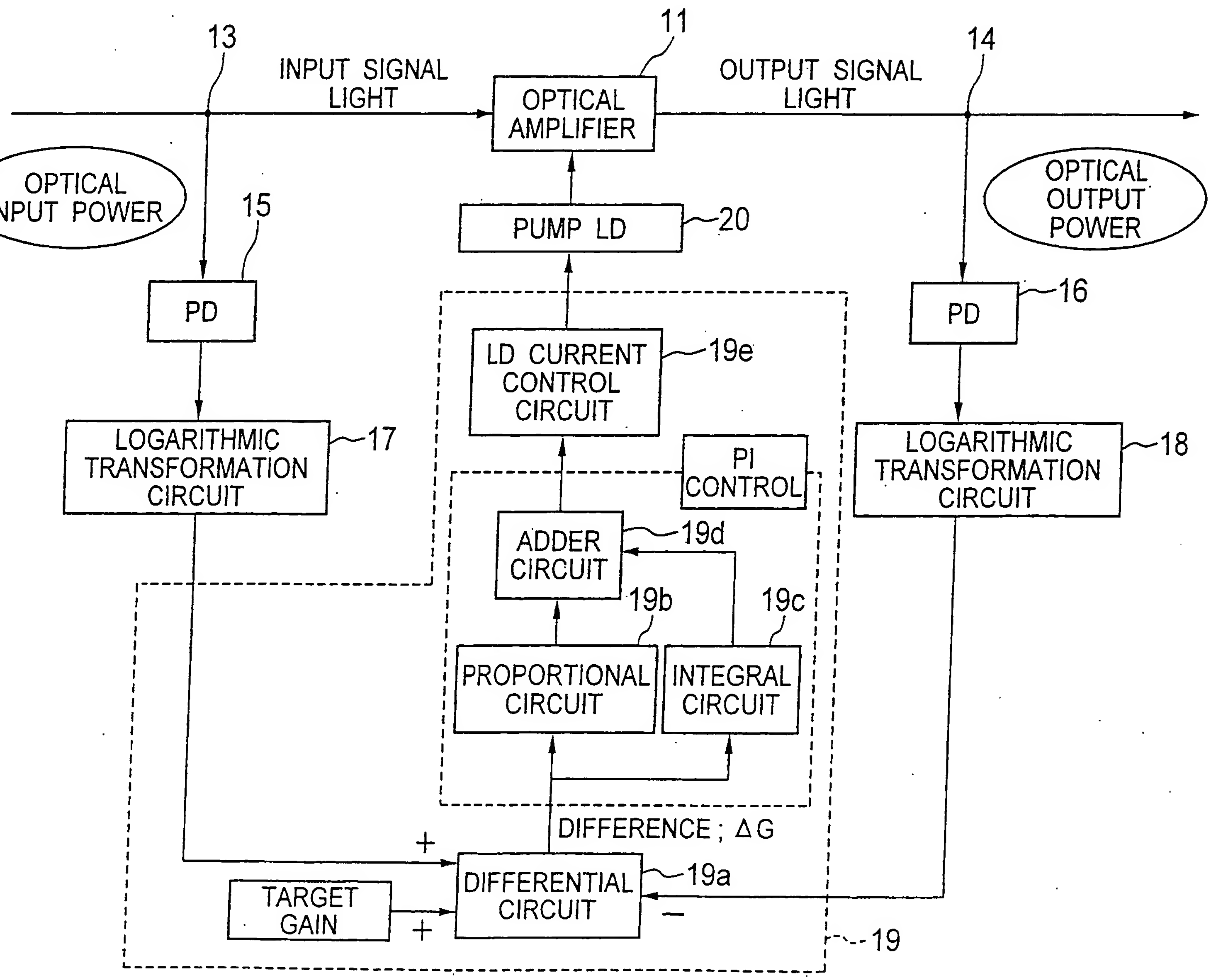
21 delay portion

30 optical amplifying apparatus

R21-R2n resistors

S1-Sn analog switches

FIG. 1



13
INPUT SIGNAL LIGHT
11
OPTICAL AMPLIFIER
OUTPUT SIGNAL LIGHT
14
OPTICAL INPUT POWER
15
PD
PUMP LD
20
OPTICAL OUTPUT POWER
PD
16
LD CURRENT CONTROL CIRCUIT
19e
LOGARITHMIC TRANSFORMATION CIRCUIT
17
PI CONTROL
LOGARITHMIC TRANSFORMATION CIRCUIT
18
ADDER CIRCUIT
19d
19b
19c
PROPORTIONAL CIRCUIT
INTEGRAL CIRCUIT
DIFFERENCE ; ΔG
+
DIFFERENTIAL CIRCUIT
19a
TARGET GAIN
+
−
19

FIG. 2

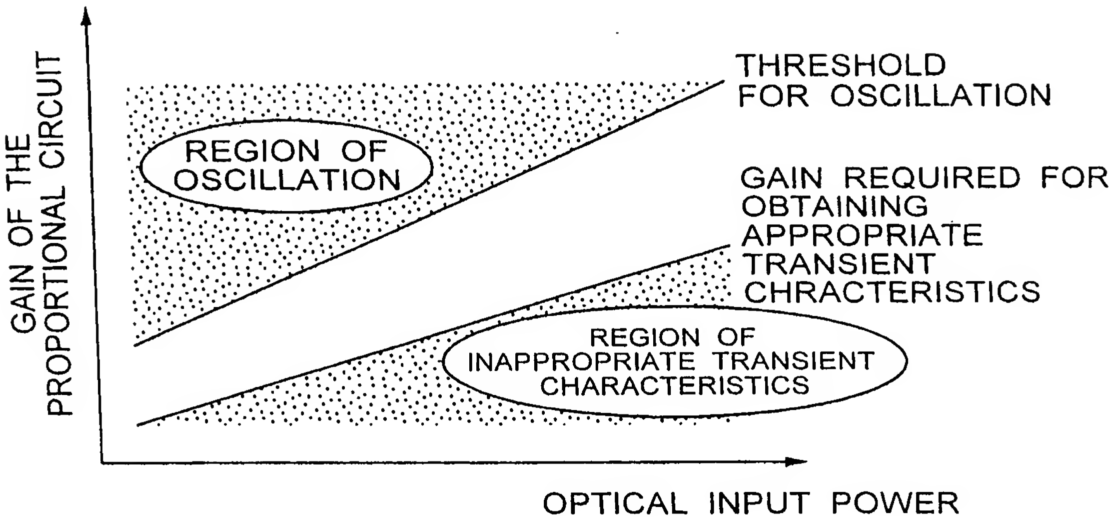

GAIN OF THE PROPORTIONAL CIRCUIT
THRESHOLD FOR OSCILLATION
REGION OF OSCILLATION
GAIN REQUIRED FOR OBTAINING APPROPRIATE TRANSIENT CHRACTERISTICS
REGION OF INAPPROPRIATE TRANSIENT CHARACTERISTICS
OPTICAL INPUT POWER

FIG. 3

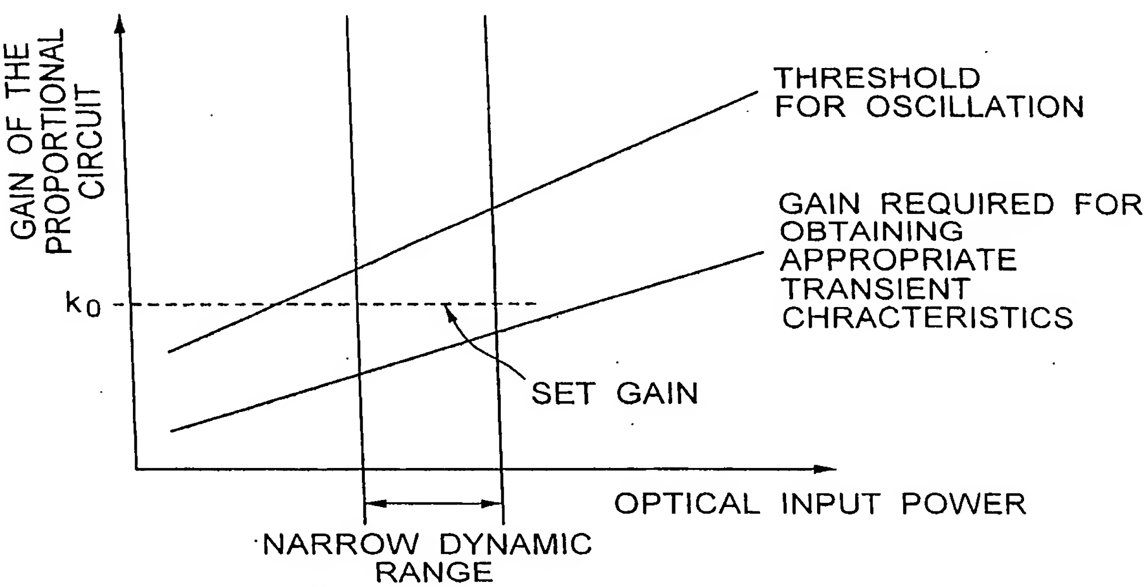

GAIN OF THE PROPORTIONAL CIRCUIT
THRESHOLD FOR OSCILLATION
GAIN REQUIRED FOR OBTAINING APPROPRIATE TRANSIENT CHRACTERISTICS
k_0
SET GAIN
OPTICAL INPUT POWER
NARROW DYNAMIC RANGE

FIG. 4

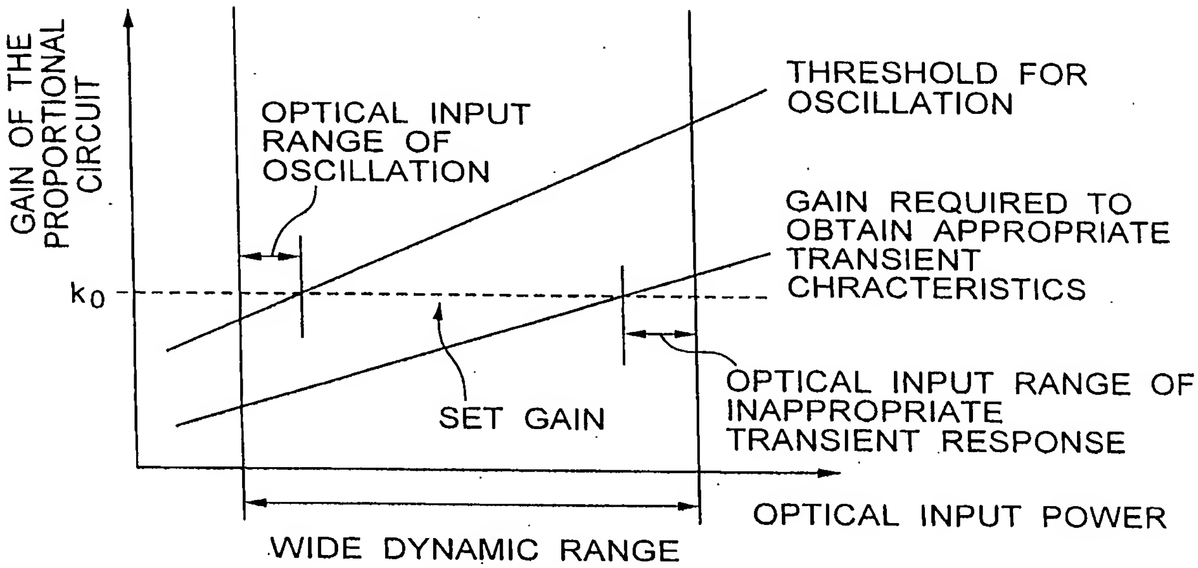

GAIN OF THE PROPORTIONAL CIRCUIT
THRESHOLD FOR OSCILLATION
OPTICAL INPUT RANGE OF OSCILLATION
GAIN REQUIRED TO OBTAIN APPROPRIATE TRANSIENT CHRACTERISTICS
k_0
SET GAIN
OPTICAL INPUT RANGE OF INAPPROPRIATE TRANSIENT RESPONSE
OPTICAL INPUT POWER
WIDE DYNAMIC RANGE

FIG. 5

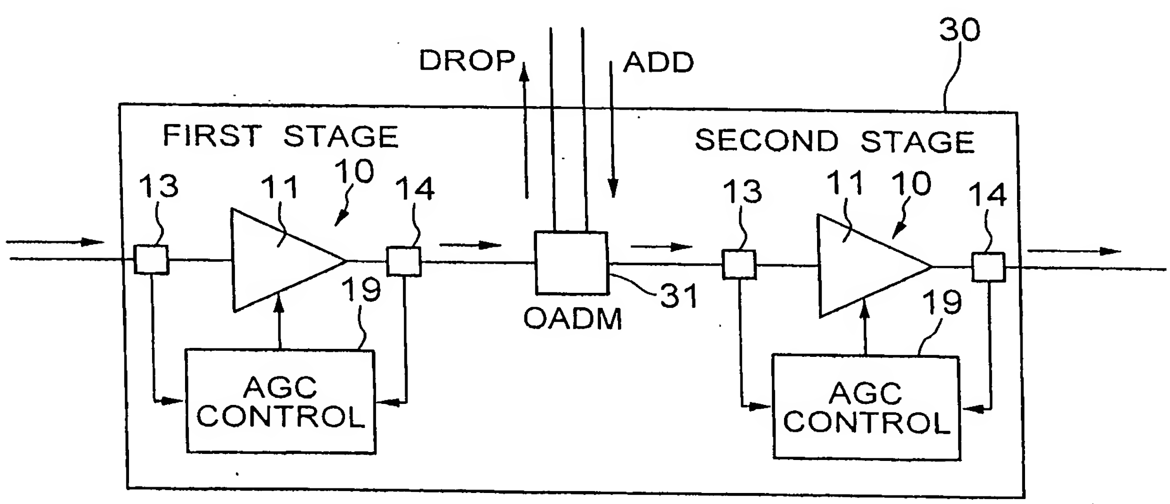
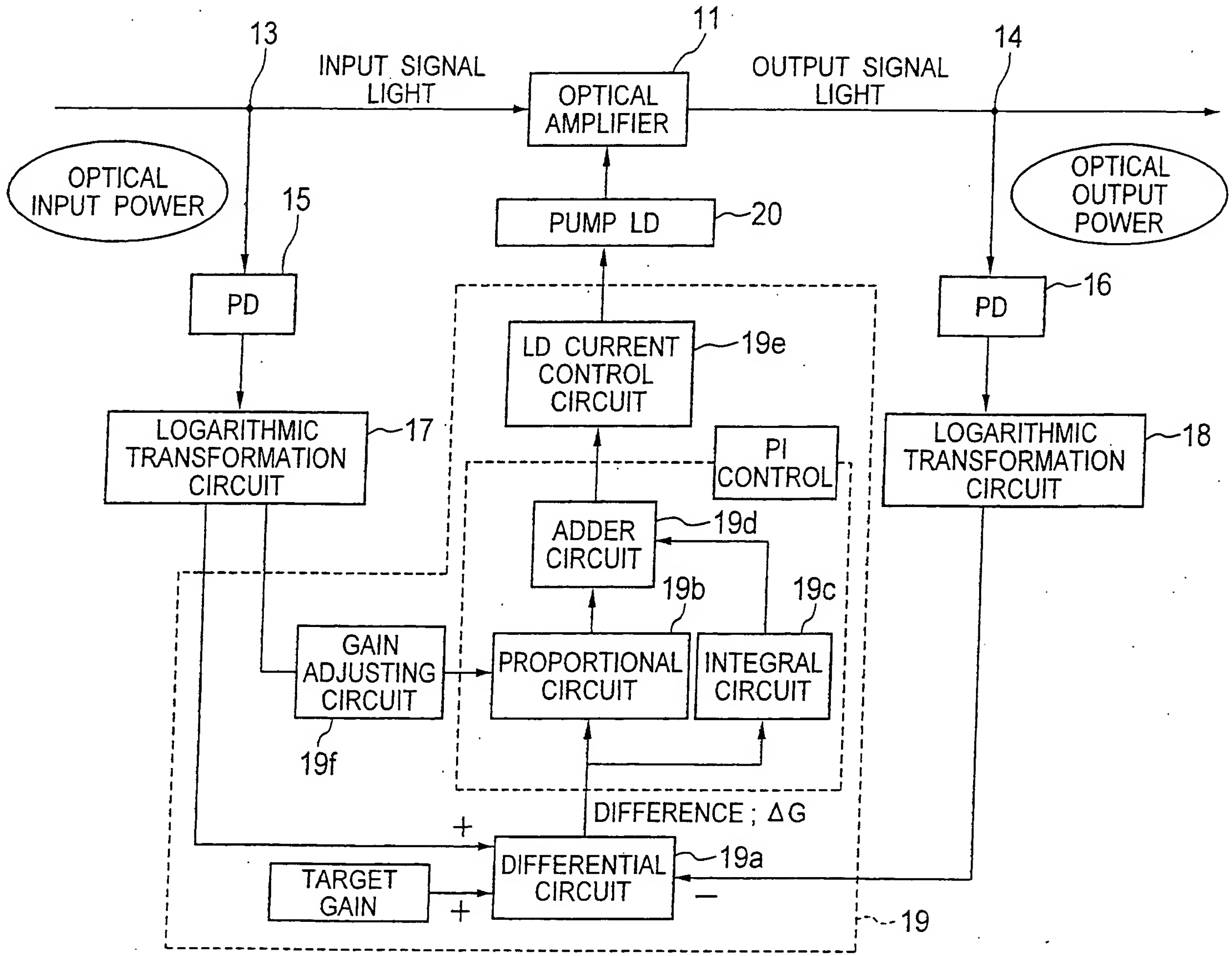

30
DROP
ADD
FIRST STAGE
SECOND STAGE
13
11
10
14
19
AGC CONTROL
OADM
31
13
11
10
14
19
AGC CONTROL

FIG. 6



13
INPUT SIGNAL LIGHT
11
OPTICAL AMPLIFIER
OUTPUT SIGNAL LIGHT
14
OPTICAL INPUT POWER
15
PD
PUMP LD
20
OPTICAL OUTPUT POWER
PD
16
LD CURRENT CONTROL CIRCUIT
19e
LOGARITHMIC TRANSFORMATION CIRCUIT
17
PI CONTROL
LOGARITHMIC TRANSFORMATION CIRCUIT
18
ADDER CIRCUIT
19d
19b
19c
GAIN ADJUSTING CIRCUIT
PROPORTIONAL CIRCUIT
INTEGRAL CIRCUIT
19f
DIFFERENCE ; ΔG
+
DIFFERENTIAL CIRCUIT
19a
TARGET GAIN
+
−
19

FIG. 7

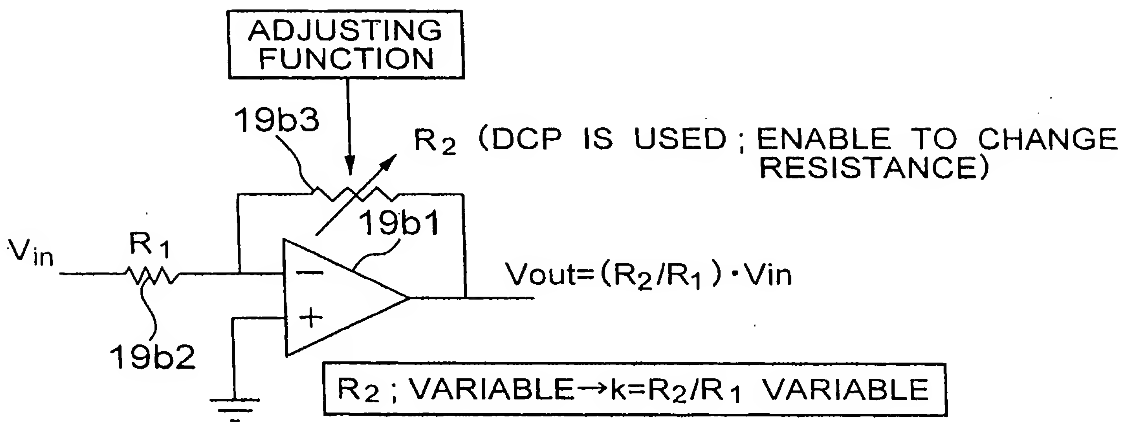

ADJUSTING FUNCTION
19b3
R2 (DCP IS USED ; ENABLE TO CHANGE RESISTANCE)
19b1
Vin
R1
Vout=(R2/R1)·Vin
19b2
R2 ; VARIABLE→k=R2/R1 VARIABLE

FIG. 8

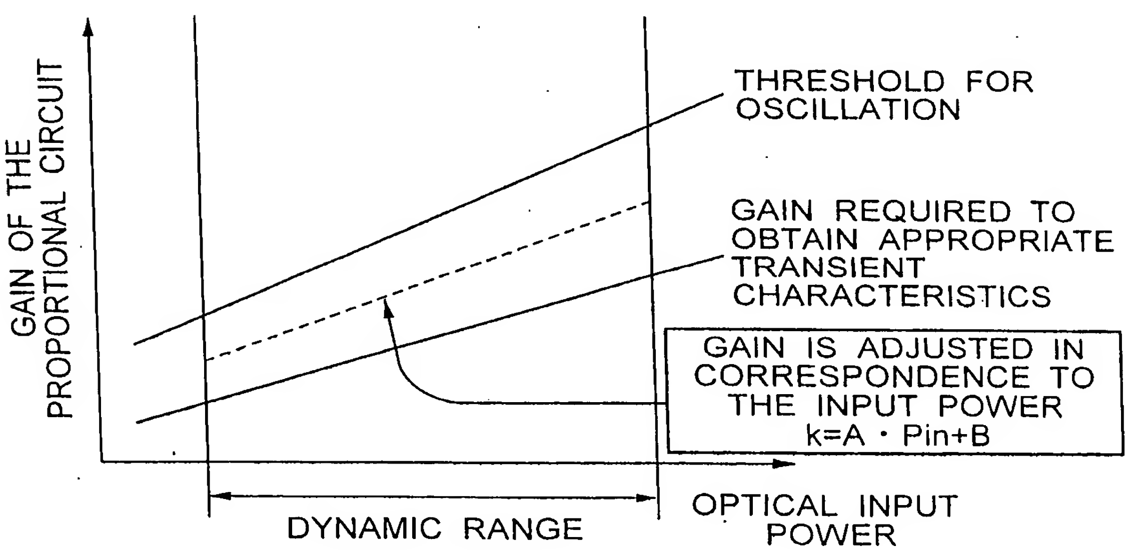
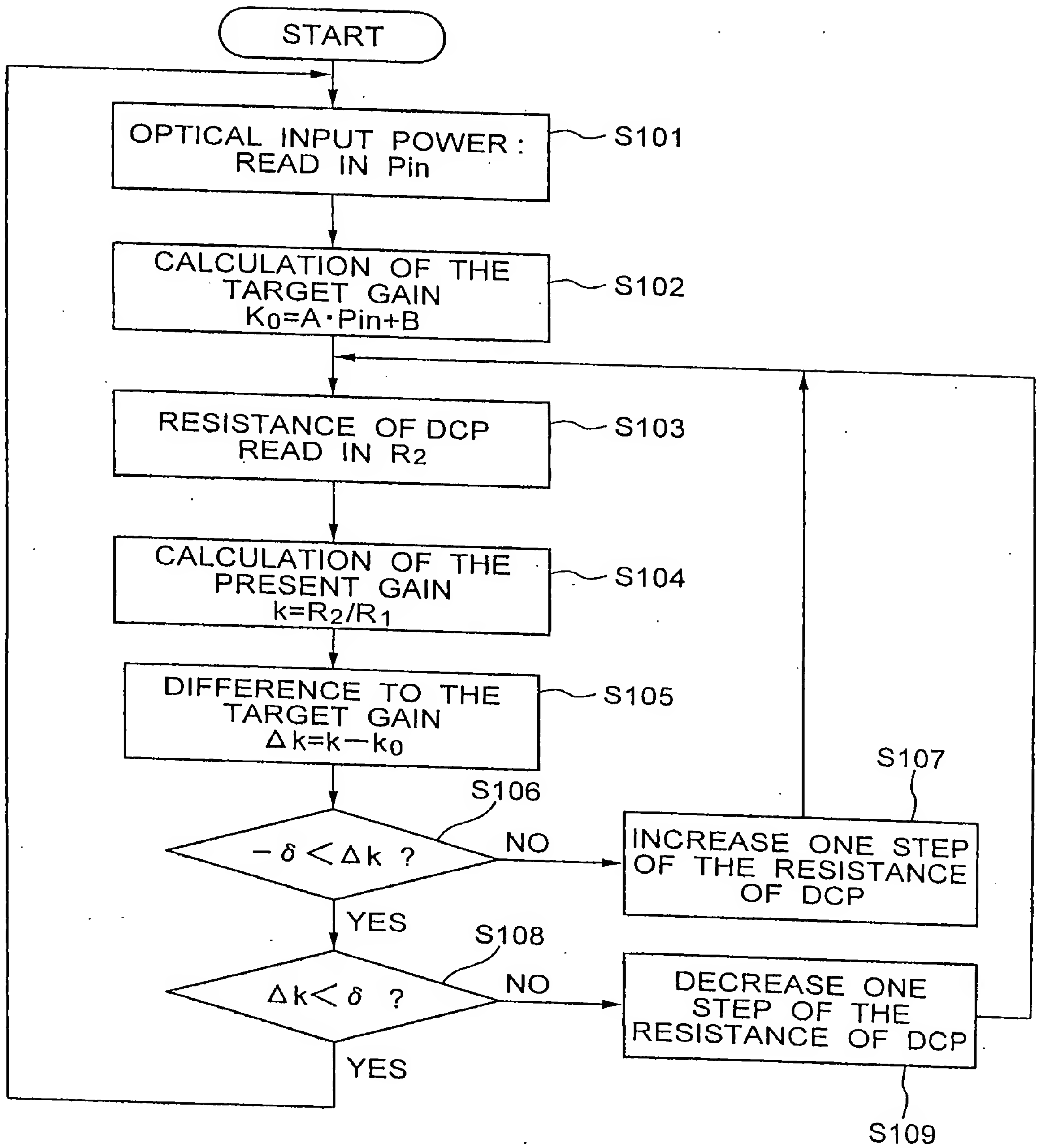

GAIN OF THE PROPORTIONAL CIRCUIT
THRESHOLD FOR OSCILLATION
GAIN REQUIRED TO OBTAIN APPROPRIATE TRANSIENT CHARACTERISTICS
GAIN IS ADJUSTED IN CORRESPONDENCE TO THE INPUT POWER k=A · Pin+B
DYNAMIC RANGE
OPTICAL INPUT POWER

FIG. 9



START
OPTICAL INPUT POWER : READ IN Pin
S101
CALCULATION OF THE TARGET GAIN
$K_0=A \cdot Pin+B$
S102
RESISTANCE OF DCP READ IN R_2
S103
CALCULATION OF THE PRESENT GAIN
$k=R_2/R_1$
S104
DIFFERENCE TO THE TARGET GAIN
$\Delta k=k-k_0$
S105
S106
$-\delta<\Delta k$?
NO
YES
INCREASE ONE STEP OF THE RESISTANCE OF DCP
S107
S108
$\Delta k<\delta$?
NO
YES
DECREASE ONE STEP OF THE RESISTANCE OF DCP
S109

FIG. 10

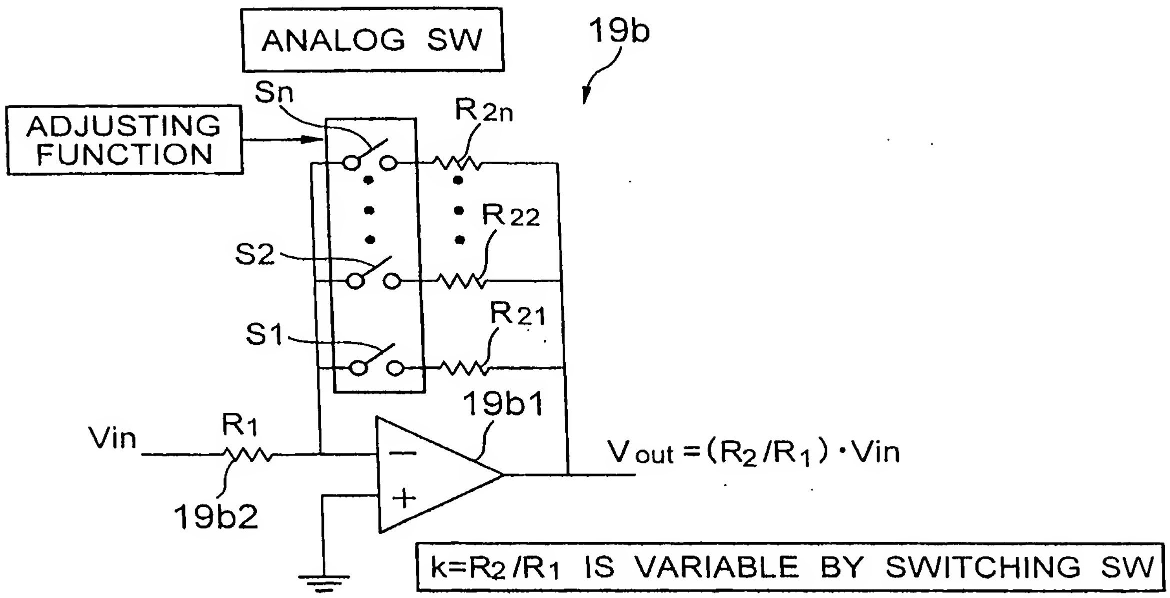

ANALOG SW
19b
ADJUSTING FUNCTION
Sn
R2n
R22
S2
S1
R21
19b1
Vin
R1
19b2
Vout = (R2/R1) · Vin
k=R2/R1 IS VARIABLE BY SWITCHING SW

FIG. 11

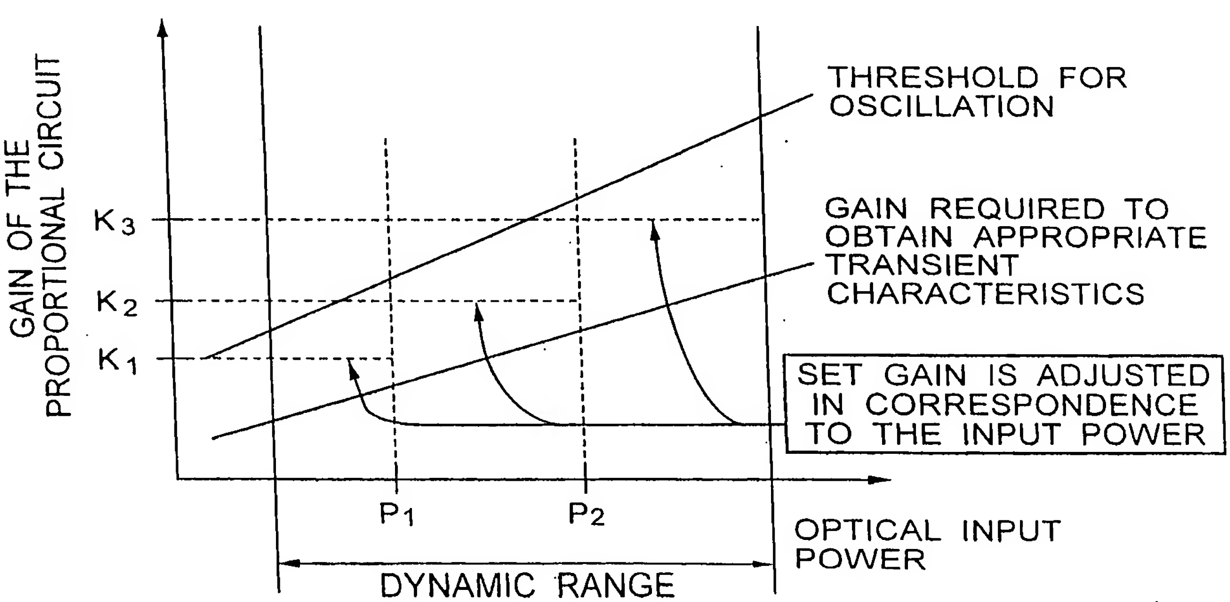

GAIN OF THE PROPORTIONAL CIRCUIT
K3
K2
K1
THRESHOLD FOR OSCILLATION
GAIN REQUIRED TO OBTAIN APPROPRIATE TRANSIENT CHARACTERISTICS
SET GAIN IS ADJUSTED IN CORRESPONDENCE TO THE INPUT POWER
P1
P2
OPTICAL INPUT POWER
DYNAMIC RANGE

FIG. 12

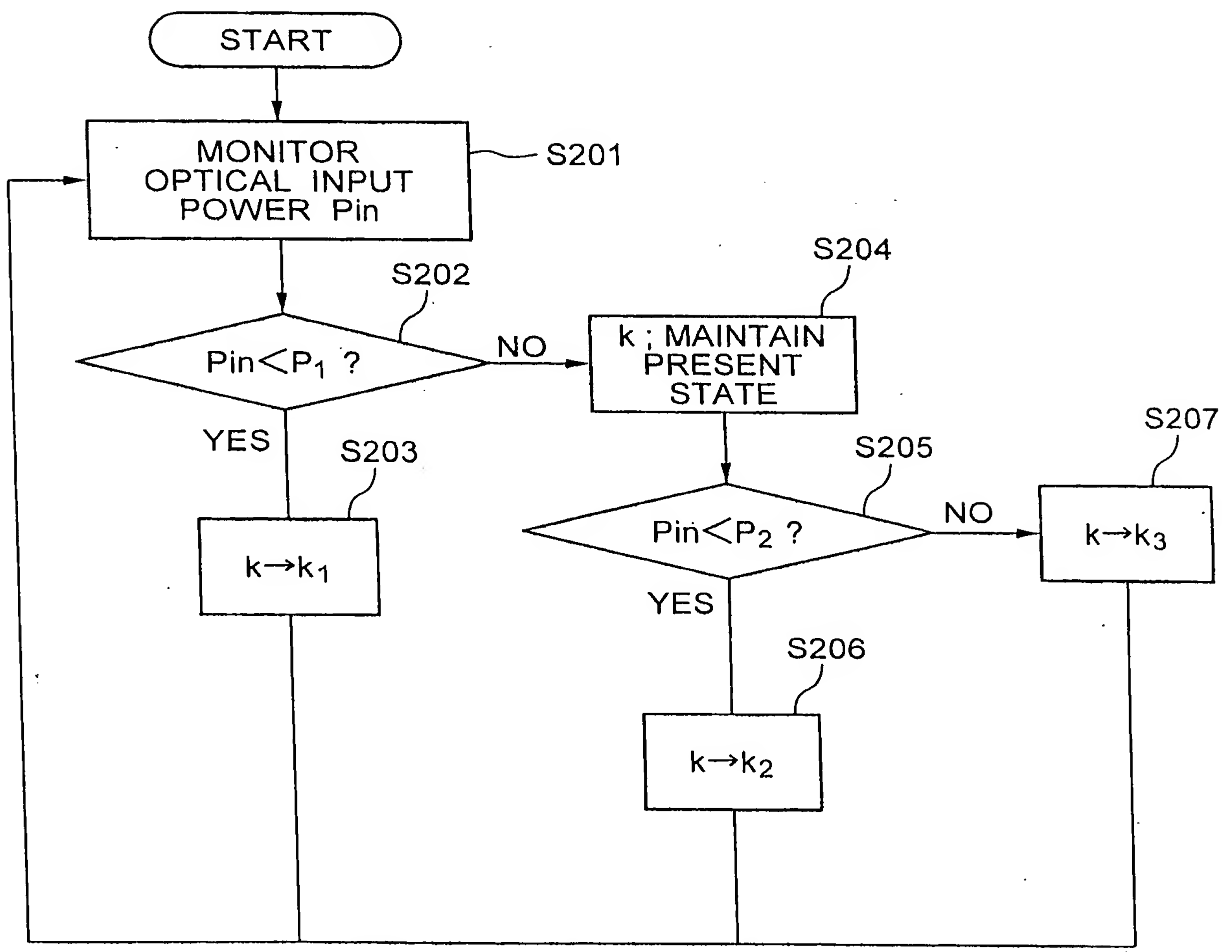

START
MONITOR OPTICAL INPUT POWER Pin
S201
S202
Pin<P1 ?
NO
YES
S203
k→k1
S204
k ; MAINTAIN PRESENT STATE
S205
Pin<P2 ?
NO
YES
S206
k→k2
S207
k→k3

FIG. 13 (a)

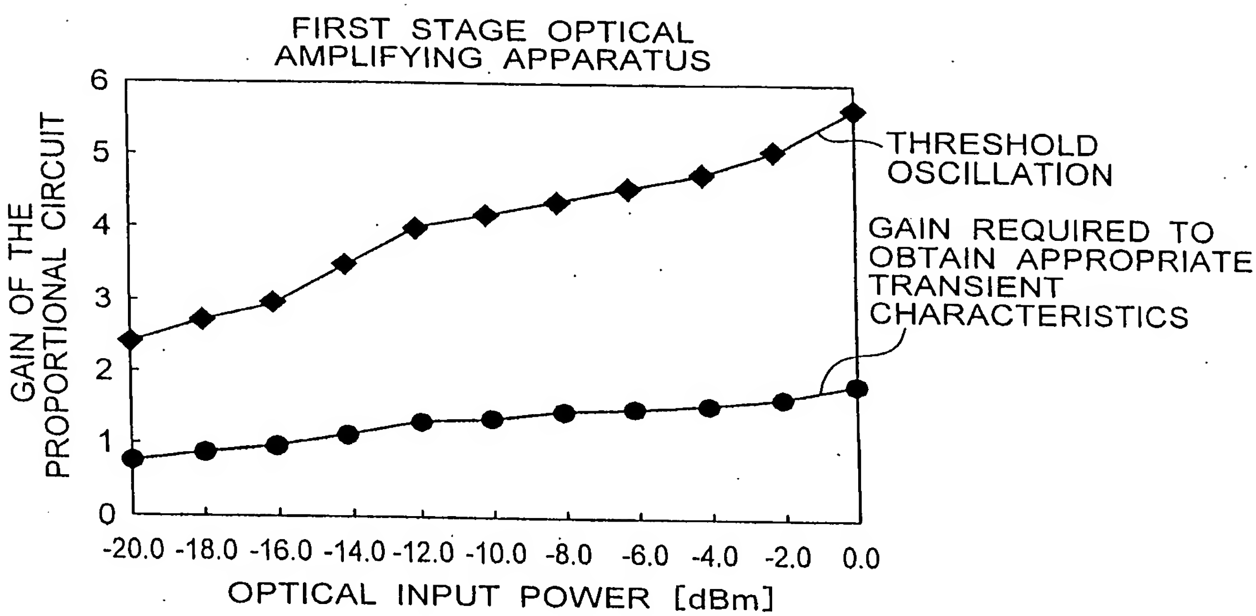


FIG. 13 (b)

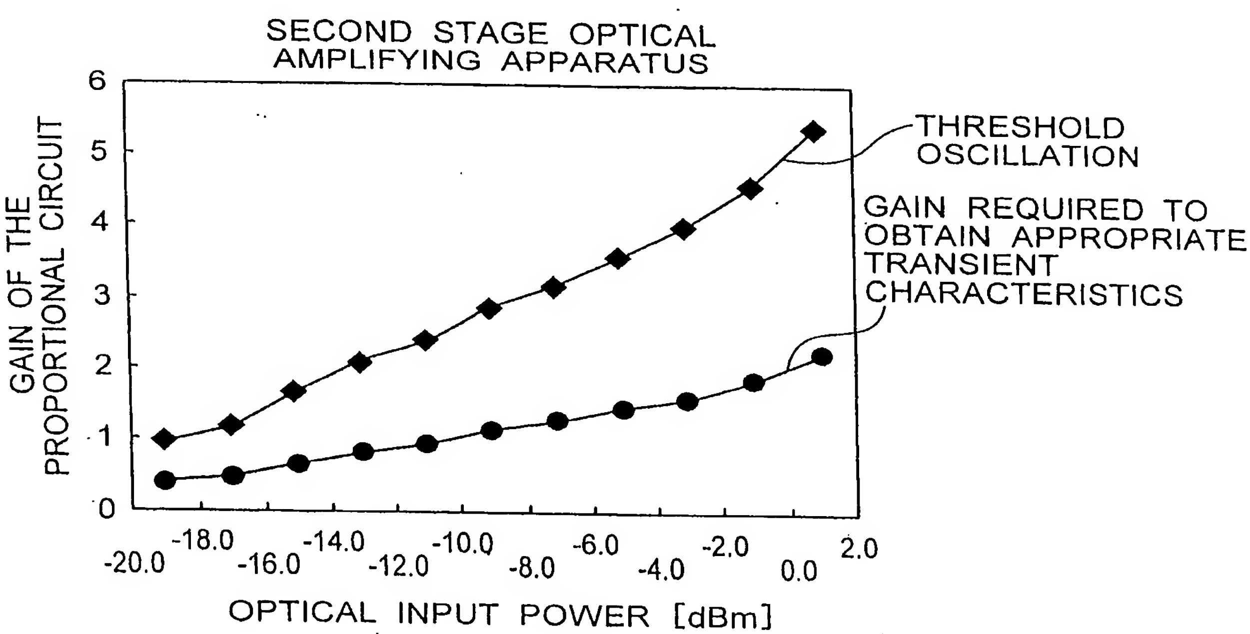


FIG. 14

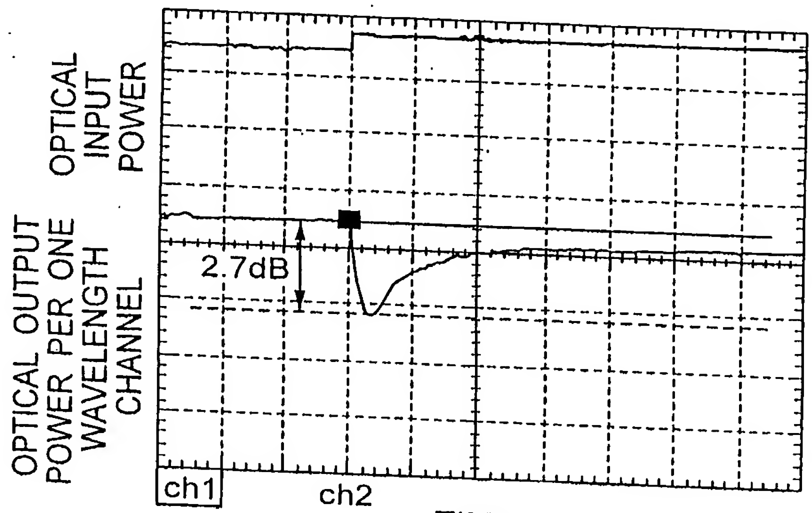
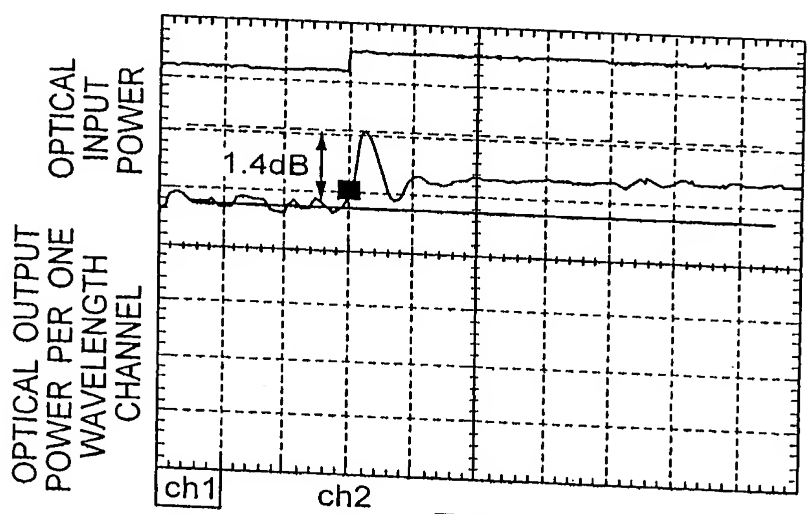
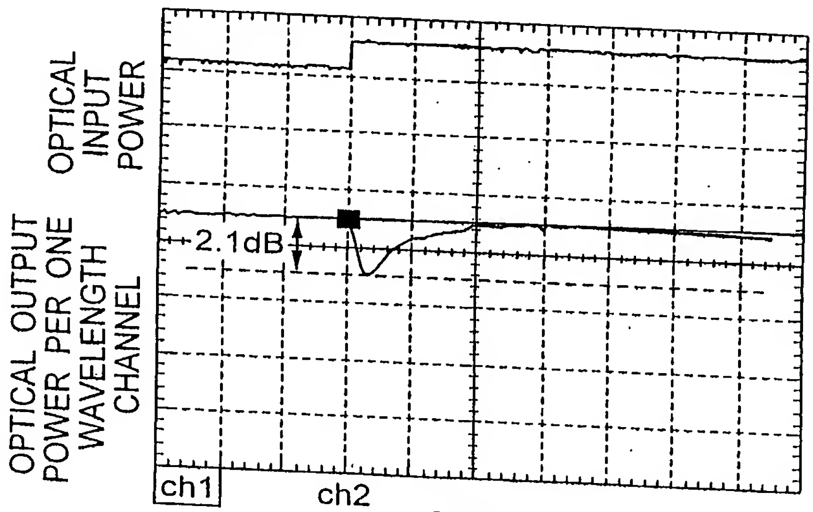
	RESULT MEASURED IN THE FIXED GAIN
(a) VICINITY OF THE UPPER LIMIT OF THE DYNAMIC RANGE −6dBm ↓ 0dBm	 TIME k=3.0 (FIRST STAGE OPTICAL AMPLIFYING APPARATUS) k=3.2 (SECOND STAGE OPTICAL AMPLIFYING APPARATUS)
(b) VICINITY OF THE LOWER LIMIT OF THE DYNAMIC RANGE −18dBm ↓ −12dBm	 TIME k=3.0 (FIRST STAGE OPTICAL AMPLIFYING APPARATUS) k=3.2 (SECOND STAGE OPTICAL AMPLIFYING APPARATUS)

FIG. 15

RESULT MEASURED IN THE THIRD EMBODIMENT

(a)
VICINITY OF THE UPPER LIMIT OF THE DYNAMIC RANGE

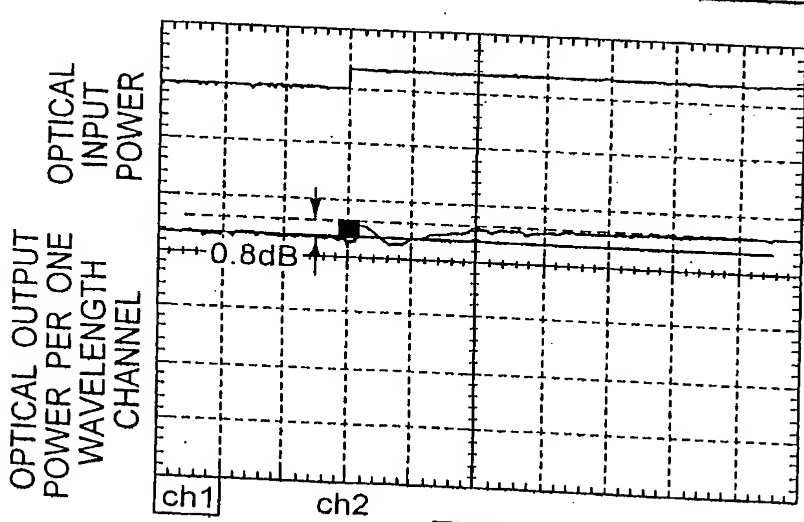
−6dBm
↓
0dBm



k=3.1 (FIRST STAGE OPTICAL AMPLIFYING APPARATUS)
k=4.3 (SECOND STAGE OPTICAL AMPLIFYING APPARATUS)

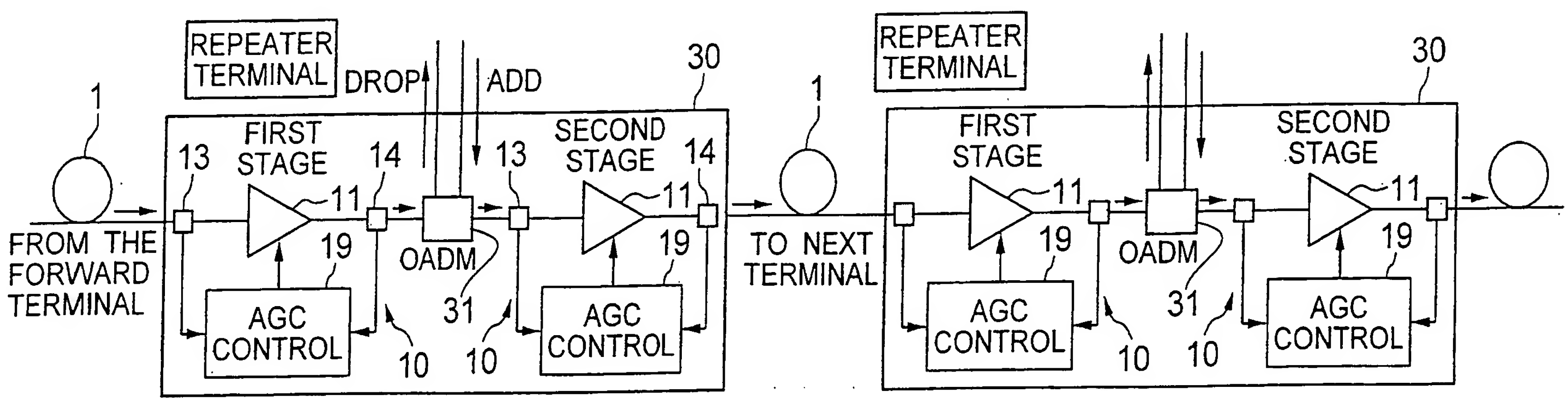
(b)
VICINITY OF THE LOWER LIMIT OF THE DYNAMIC RANGE

−18dBm
↓
−12dBm



k=1.7 (FIRST STAGE OPTICAL AMPLIFYING APPARATUS)
k=1.2 (SECOND STAGE OPTICAL AMPLIFYING APPARATUS)

FIG. 16



REPEATER TERMINAL
DROP
ADD
30
1
FIRST STAGE
SECOND STAGE
13
14
11
19
OADM
31
10
AGC CONTROL
FROM THE FORWARD TERMINAL
TO NEXT TERMINAL
REPEATER TERMINAL
FIRST STAGE
SECOND STAGE
OADM
AGC CONTROL

FIG. 17

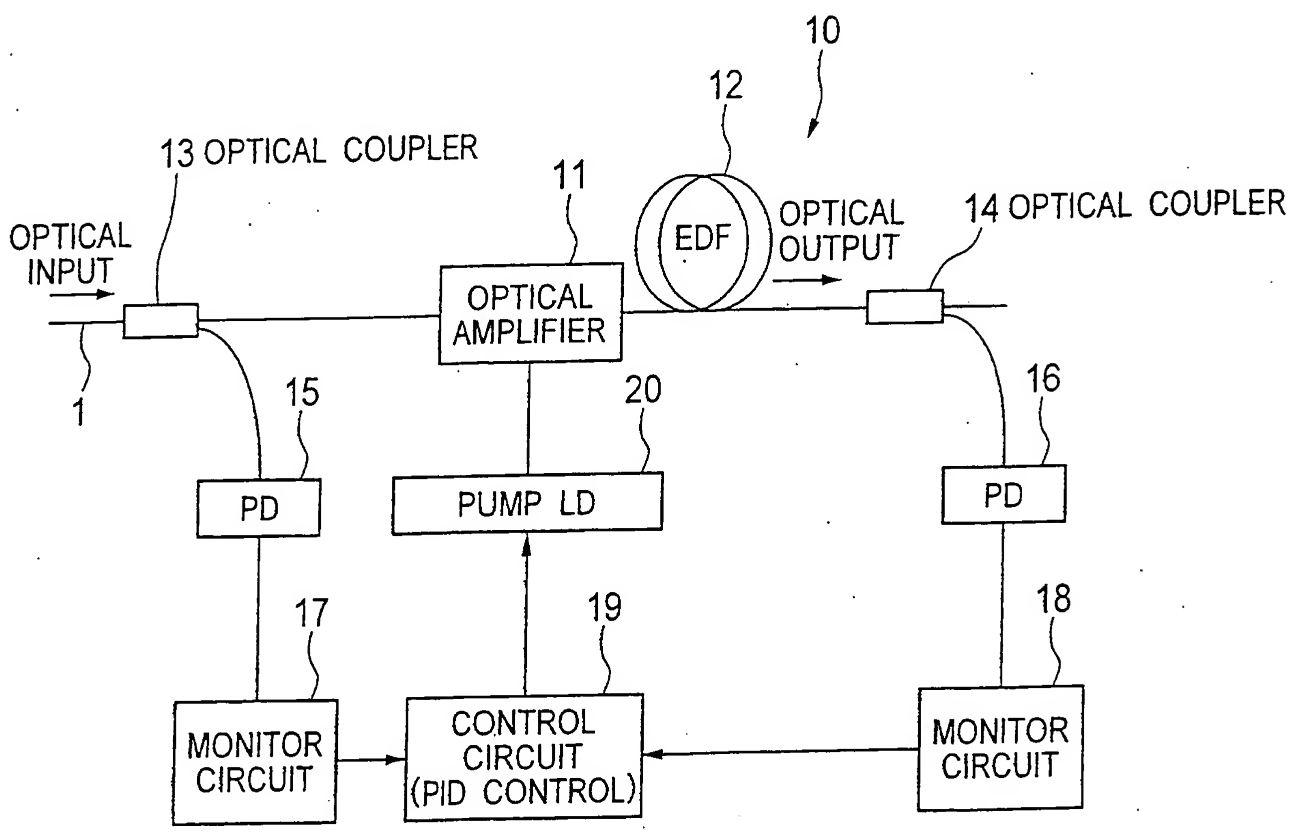
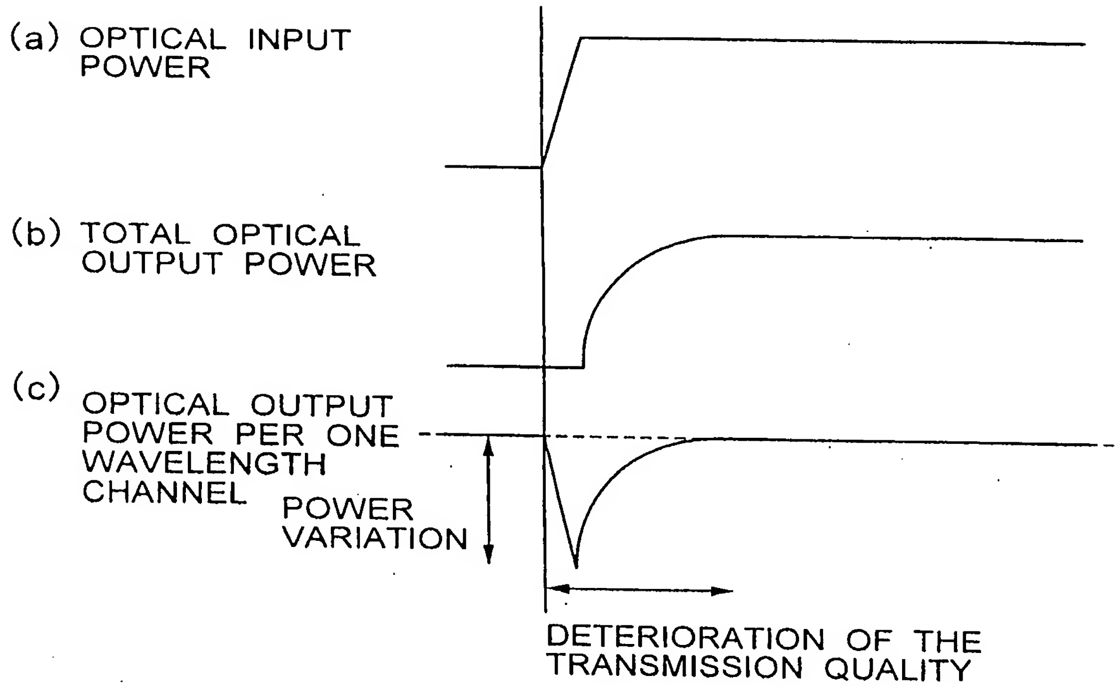
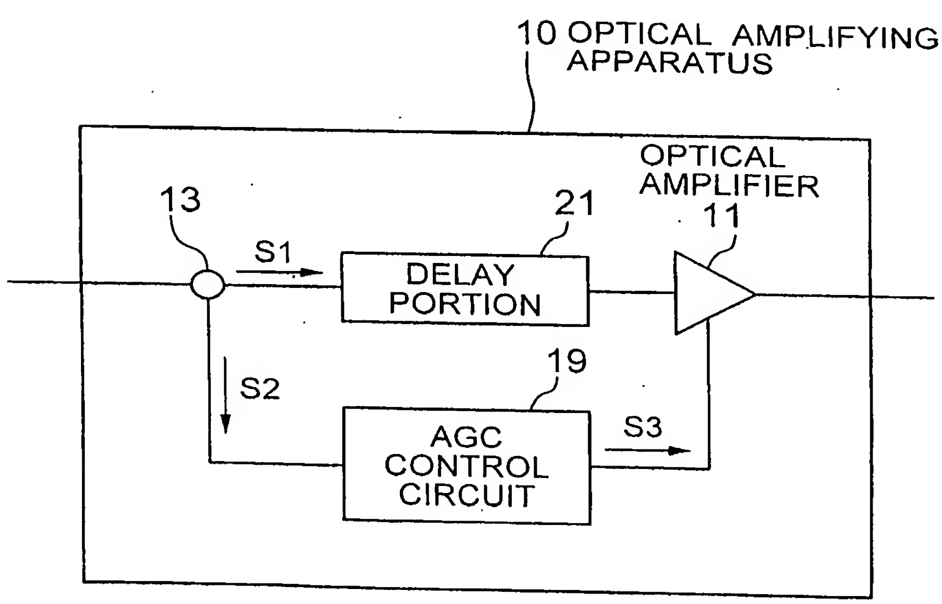

10
12
13 OPTICAL COUPLER
11
EDF
OPTICAL OUTPUT
14 OPTICAL COUPLER
OPTICAL INPUT
OPTICAL AMPLIFIER
1
15
20
16
PD
PUMP LD
PD
17
19
18
MONITOR CIRCUIT
CONTROL CIRCUIT (PID CONTROL)
MONITOR CIRCUIT

FIG. 18



(a) OPTICAL INPUT POWER
(b) TOTAL OPTICAL OUTPUT POWER
(c) OPTICAL OUTPUT POWER PER ONE WAVELENGTH CHANNEL
POWER VARIATION
DETERIORATION OF THE TRANSMISSION QUALITY

FIG. 19



10 OPTICAL AMPLIFYING APPARATUS
OPTICAL AMPLIFIER
11
13
21
S1
DELAY PORTION
19
S2
AGC CONTROL CIRCUIT
S3

[Name of the document]
Abstract

[Summary]

[Problem to be solved]
Problem to be solved in the invention is to provide an optical amplifying method, an optical amplifying apparatus and an optical amplified transmission system, in which the space occupied by the optical fiber may be reduced to realize the downsizing of the apparatus, and the control constant of the AGC circuit is adjusted to be an appropriate value even when the optical input power to the optical amplifier abruptly varies under operation, thus enabling high speed optical signal transmission and stable optical amplifier control.

[Means to solve the problem]
A proportional constant adjusting circuit 19f is arranged in the AGC circuit 19 of the optical amplifying apparatus, and the proportional constant of the proportional circuit 19b is continuously adjusted in correspondence to the optical input power monitored by the PD 15 and the logarithmic transformation circuit 17.
The AGC circuit 19 controls the pump LD based on the monitored optical input/output power so as to control the gain of the optical amplifier 11 to be a requested value.

[Selected drawing]
Fig. 6